Egyptian Journal of Ear, Nose, Throat and Allied Sciences (2013) **14**, 123–128

Egyptian Society of Ear, Nose, Throat and Allied Sciences

Egyptian Journal of Ear, Nose, Throat and Allied Sciences

www.ejentas.com

EJENTAS

ORIGINAL ARTICLE

Effect of coronary stent application on the audiovestibular functions in patients with ischemic heart disease

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Received 17 March 2013; accepted 19 May 2013
Available online 17 June 2013

KEYWORDS

Ischemic heart disease;
Coronary stents;
Labyrinthine microcirculation;
Audio-vestibular

Abstract Labyrinthine function is tightly coupled to proper homeostasis. Perturbations in labyrinthine microcirculation can lead to significant cochlear and/or vestibular dysfunction. Indeed, no studies were conducted to examine the effect of improvement in cardiac performance after coronary stent application on either hearing or vestibular function. This study included 30 patients presenting to the Catheterization Unit in Sohag University Hospitals. Their age ranged from 41 to 60 years. Those patients were suffering from ischemic heart disease and proved to be candidates for Percutaneous Coronary Intervention (PCI) and stenting through a list of pre-operative investigations that included: Electrocardiography (ECG), Echocardiography and Coronary angiography. A full battery of audiovestibular investigations was conducted both preoperatively and postoperatively. Significant differences were encountered between preoperative and postoperative auditory brainstem response (ABR) latency measures, transient evoked otoacoustic emission (TEOAE), vestibular evoked myogenic potentials (VEMP) and Computerized Dynamic Posturography (CDP) tests. Both TEOAE and VEMP proved to be reliable indicators of defective labyrinthine circulation. Severity of chest pain as well as its duration proved to be the best predictors of the degree of total stenosis of coronary arteries. It can be concluded that affection of the labyrinthine peripheral microcirculation is an intimate consequence of deterioration of cardiac output (COP) secondary to ischemic heart disease.

1. Introduction & rationale

Labyrinthine function is tightly coupled to proper homeostasis. Perturbations in labyrinthine microcirculation can lead to significant cochlear and/or vestibular dysfunction. The etiology of many otologic disorders, including sudden sensorineural hearing loss, presbyacusis, noise-induced hearing loss, and certain vestibulopathies, is suspected of being related to alterations in blood flow. A reduction in blood supply to the

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Peer review under responsibility of Egyptian Society of Ear, Nose, Throat and Allied Sciences.

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http://dx.doi.org/10.1016/j.ejenta.2013.05.004

cochlea is likely, in part, responsible for reduced auditory sensitivity associated with chronic noise exposure and aging [1].

Cardiovascular disease (CVD) has been identified as a risk factor for hearing loss in older adults. In an early study, Rosen and Olin (1965) found that 40–59-year-old individuals with heart disease had poorer hearing sensitivity than individuals of similar age without heart disease [2]. Furthermore, Rubinstein et al. (1977) reported that 65–85-year-old adults with CVD and signs of peripheral circulation disorders had significantly higher mean thresholds (4000–8000 Hz) than people of comparable age without CVD [3].

Conversely, no correlations were found between audiometrically assessed hearing loss and CVD risk factors in 1000 subjects [4]. There was no correlation between self-reported hearing problems and hypertension, angina pectoris, and previous myocardial infarction (MI) in the Copenhagen Male Study (a prospective epidemiologic study of CVD; Parving et al., 1993). Karamitsos et al. (1996) reported no significant differences in pure-tone audiometry in individuals with ischemic heart disease compared to age-matched healthy individuals, although there were significant peak auditory brainstem response latency differences between the groups [5,6].

Since the introduction of percutaneous transluminal coronary angioplasty (PTCA), the first use of coronary stenting in clinical practice in 1986 was the major breakthrough in the treatment of patients with coronary artery disease. Coronary stenting was introduced to combat two limitations of conventional PTCA: acute vessel closure and late lumen renarrowing. Now, after many years of continuous refinement, stenting has become the dominant percutaneous coronary intervention [7].

CVD had been declared by many authors to be one of the general causes of dizziness [8]. However, no studies were conducted to examine the vestibular function in such patients. Actually, the real effect of a circulatory deficit that follows coronary artery disease on the human labyrinth still looks to be controversial and unclear. Moreover, no studies were conducted to examine the effect of improvement in cardiac performance after coronary stent application on either hearing or vestibular function. Therefore, this study was designed to address the effect of ischemic heart disease and the effect of improvement in cardiac performance following stent application on the audiovestibular functions.

2. Materials and method

2.1. Subjects

Thirty patients were chosen from a total of 49 referred from the Cardiology Clinic to the Catheterization Unit in Sohag University Hospitals from the Cardiology Outpatient Clinic. Those patients were selected according to the following criteria:

1. Age ranged from 40 to 60 years.
2. Any degree of anginal chest pain.
3. Indicators of ischemic heart disease:
   a. ECG: Elevated ST segment or inverted T wave; OR
   b. Echocardiography: Wall motion abnormalities or abnormal EF; OR
   c. Both.
4. Subjects with or with no audiovestibular complaints were included.
5. Subjects, who were bedridden, have neurological disorders or history of ototoxic drug intake, were excluded.
6. Candidates for PCI and Stenting.

2.2. Method

Each individual in this study was subjected to the following before coronary stent application:

A. Cardiologic investigations:
1. Detailed medical history, clinical examination and laboratory data focusing upon anginal chest pain, risk factors (D.M., hypertension, smoking, and/or dyslipidemia).
2. Electrocardiography (ECG):
3. Echocardiography: The presence or absence of segmental wall motion abnormalities was examined. Both wall motion abnormalities and ejection fraction (EF) are measured.
4. Coronary angiography (intraoperatively): For all patients baseline coronary angiography was performed using the femoral artery approach. Multiple projections were recorded to visualize the lesion properly. These angiograms were stored on the computer disk of a digital acquisition X-ray system that permits digital caliber measurements of the arterial segment.

B. Audiological investigations:
1. Thorough history of hearing, dizziness and medical disorders.
2. Otoscopic examination.
3. Hearing evaluation including:
   a. Pure-tone audiometry using two-channel audiometer Madsen; Model: Orbiter 922. Air conduction thresholds at 0.25 kHz through 8 kHz. And bone conduction thresholds at 0.5 kHz through 4 kHz.
   b. Speech audiometry: This included speech reception threshold (SRT) using Arabic spondee words and word discrimination testing (DS%) using Arabic phonetically balanced (PB) words [9].
   c. Acoustic immittance testing using Immittancemeter Amplaid; Model: 775. It included tympanometry and acoustic reflex threshold measurement
   d. Neuro-otologic Auditory Brainstem Response (ABR) using Evoked Potentials System; Model: Spirit Nicolet. Click ipsilateral recording stimuli were used at intensities of 90 dBnHL and 50 dBnHL in each ear separately. Surface electrodes were attached to both mastoid processes and the forehead as a ground electrode. Wave V was detected and its latency was measured and recorded.
   e. Transient Evoked Otoacoustic Emission (TEOAE) using (TEOAE) analyzer; Model: Madsen Capella: For subjects with normal otoscopy and tympanometry. The probe is sealed in the external canal for right and left ears. A response is considered present whenever there was an emission at 3 dB signal/noise ratio or more in any frequency band [10]. Accordingly, the results were categorized into:

- Pass: The response is 3 dB or more in each of the tested frequency bands.
- Partial pass: The response was present in at least two of the tested frequency bands, but not all.
- Fail: No cochlear response is detected at any of the tested frequency bands.

C. Vestibular investigations:

1. VNG using (VNG) Set; Model: ICS version 5. Classic VNG test battery was conducted searching for spontaneous, gaze-evoked, oculomotor, positional and positioning tests. Bithermal caloric test was fulfilled at the end
2. Vestibular evoked myogenic potential (VEMP) using Evoked Potentials System; Model: Spirit Nicolet. Using monaural alternating acoustic click stimuli at an intensity of 95 dB nHL. EMG activity was recorded on the sternocleidomastoid muscles (SCM) with the patient in the sitting position.
3. Computerized Dynamic Posturography (CDP) Model: Neurocom Equitest. The test included:

a. Sensori-Organization Test (SOT).
b. Motor Control Test (MCT):

Each individual in this study was subjected to the same procedures one month after coronary stent application.

2.3. Statistical plan

The obtained data were analyzed statistically using SPSS 16 program for Windows 7 (Statistical Package for Social Sciences). The statistical analysis consisted of the following models:

1. Paired *t*-test: This model was used to compare the preoperative results with the postoperative results for both audiological and vestibular tests.
2. One sample *t*-test: This model was used to compare the preoperative results of audiological and vestibular tests with our laboratory normative data.
3. Chi-square test: This model was used to study the correlation between qualitative data for both cardiologic and audiovestibular tests.
4. Spearman's correlation coefficient: This model was used to study the effect as well as the relation between preoperative and postoperative qualitative data.
5. Stepwise regression analysis: A regression assesses whether predictor variables account for variability in a dependent variable.

3. Results

A total number of 30 patients (24 males and six females) were included in this study. Their age ranged from 41 to 60 years (Mean = 51.27 yrs, SD = 5.86 and Median = 51.5, Mode = multiple but the youngest was 47 years).

Most of the patients (n = 19) presented with Grade I chest pain i.e. chest pain appeared only during extraordinary exertion at work or recreation [11]. The duration of chest pain varied from 1 to 12 months with a mean value of 6.07 ± 3.46. The patients were classified into two groups: Group I with grade I anginal chest pain and Group II with grade II anginal chest pain.

3.1. Audio vestibular results

No subject complained of hearing difficulty; however five had tinnitus while seven patients had experienced dizziness. All subjects had normal hearing sensitivity except for two (had mild high frequency sensorineural hearing loss) with normal middle ear functions.

The latency of waves I, III, and V, in all ears, lied within the normal range for our laboratory normative data for latency-intensity functions. When the preoperative results are compared with postoperative ones, significant differences are explicit especially for wave I.

Forty-seven ears (25 right and 22 left) recorded a **PASS** in TEOAE both preoperatively and postoperatively. Additionally, three ears (1 right and 2 left) recorded a **Partial PASS** in TEOAE both preoperatively and postoperatively. However, out of 13 ears that had a **Partial PASS** preoperatively, 10 ears had a **PASS** postoperatively.

Worth noting, that VNG subtests including the caloric test were within normal both preoperatively and postoperatively for all patients.

There was a significant difference between preoperative and postoperative VEMP results. Out of the 10 ears that had abnormal VEMP preoperatively, four changed to normal VMP postoperatively.

In computerized dynamic posturography, the scores of the sensory organization test (SOT) and the motor control test (MCT) improved significantly after stent application. However, four patients had abnormal conditions 5 and 6 in sensory organization test (SOT) preoperatively. They were reduced to only one postoperatively.

Chest pain duration and grade were the best predictors of the degree of total stenosis.

4. Discussion

Chest pain, the main complaint that pushed the patients of this study to visit the cardiology clinic, was used as a tool of classification. Two groups were born: One for the milder degree of chest pain (grade I) and the other for the worse degree (grade II). Each of these groups had its own distinct profile (Table 1). In fact subjects in grade 1 are the most challenging to suspect or diagnose cardiac dysfunction when they suffer tinnitus or dizziness. They need much care in history taking and in depth examination.

The milder degree of anginal chest pains explains the long duration that passed before the patient's search for medical help. As the pain only popped up during extraordinary exertion, this made the matter tolerable for the daily ordinary events.

All those who were selected for the study were carrying a package of risk factors including: hypertension, diabetes mellitus, smoking and dyslipidemia (Table 1). Smoking was exclusively preserved for male patients. In Egypt, females are mostly nonsmokers. Collectively, dyslipidemia and smoking were the most prevalent factors in patients with grade I anginal

Table 1 Profile of group I & group II across different indices.

Groups	Group I		Group II	
Age (years)	53.11 (X)	5.5 (SD)	48.09 (X)	5.2 (SD)
Duration of chest pain (years)	6.05 (X)	3.5 (SD)	6.09 (X)	3.6 (SD)
Hypertension	7 (N)	36.84%	7 (N)	63.63%
D.M.	9 (N)	47.36%	6 (N)	54.54%
Smoking	15 (N)	78.94%	9 (N)	81.81%
Dyslipidemia	17 (N)	89.47%	4 (N)	36.36%

X = mean, SD = standard deviation, N = number of patients.

Table 2 Correlation test of chest pains, preoperative ECG, Echocardiography (WMA & EF), and total stenosis of coronary arteries.

	Degree of stenosis in LADA	Degree of stenosis in LCA	Degree of stenosis in RCA	Total degree of stenosis
Correlation with grade of chest pain	0.12	0.18	0.21	0.46
P-Value	0.52	0.33	0.24	0.01**
Correlation with ECG	0.06	0.19	0.47	0.62
P-Value	0.78	0.31	0.008**	0.001***
Correlation with Echocardiography (WMA & EF)	0.01	0.02	0.24	0.16
P-Value	0.97	0.84	0.19	0.04*

WMA = wall motion abnormalities, EF = ejection fraction, LADA = left anterior descending artery, LCA = left circumflex artery, RCA = right coronary artery, total stenosis = stenosis score (LADA + LCA + RCA), 0 = no stenosis, 1 = mild stenosis, 2 = moderate stenosis, 3 = severe stenosis.

Table 3 Distribution of audiovestibular complaints among patients.

Audiovestibular complaints	Number of patients	Associated symptoms	%
No audiovestibular complaints	16	None	53.3
Bilateral diminution of hearing	2	One had right sided continuous hissing tinnitus and the other had right sided intermittent humming tinnitus.	6.7
Tinnitus in both ears	5	None	16.7
Dizziness	7	None	23.3

Table 4 Results of preoperative and postoperative auditory brainstem response (ABR) latencies in milliseconds among patients.

ABR waves		Pre-stent application	Post-stent application	*P* Value
		Mean ± SD	Mean ± SD	
Wave I at 90 dBnHL	Rt ear	1.52 ± 0.0276	1.48 ± 0.0234	0.002**
	Lt ear	1.53 ± 0.025	1.49 ± 0.027	0.001***
Wave III at 90 dBnHL	Rt ear	3.56 ± 0.0887	3.54 ± 0.0688	0.012*
	Lt ear	3.56 ± 0.084	3.53 ± 0.071	0.011*
Wave V at 90 dBnHL	Rt ear	5.636 ± 0.110	5.643 ± 0.128	0.011*
	Lt ear	5.62 ± 0.105	5.60 ± 0.086	0.013*
Wave V at 50 dBnHL	Rt ear	6.03 ± 0.092	5.98 ± 0.192	0.143
	Lt ear	6.01 ± 0.085	5.99 ± 0.056	0.061

chest pain (group I), while smoking remained solely on the top in patients with grade II (group II).

A highly significant correlation was found between the distribution of coronary artery stenosis and the degree of chest pain, ECG and EF of echocardiography (Table 2). All of the risk factors were controlled before conduction of the partial correlation test.

All the patients who met the candidacy criteria were referred to the Audiology & Vestibular Clinic at Sohag University hospitals. Only the data of the patients, who further

Table 5 Results of preoperative and postoperative transient evoked otoacoustic emission (TEOAE).

TEOAE [Right ear]		Postoperative TEOAE		Total
		Pass	Partial pass	
Preopertive TEOAE	Pass	25	0	25
	Partial pass	4	1	5
Total		29	1	30
Pearson chi-square value		5.172		
P-Value		0.023*		
TEOAE [Left ear]		Postoperative TEOAE		Total
		Pass	Partial pass	
Preopertive TEOAE	Pass	22	0	22
	Partial pass	6	2	8
Total		28	2	30
Pearson chi-square value		5.893		
P-Value		0.015*		

had a stent applied, were included in the study. Of those patients, 14 had a strong motivation for this visit as they had audiovestibular complaints (Table 3) while the rest considered it as a part of a full medical evaluation.

Among the complaining patients, dizziness and tinnitus were the major complaints. Hearing loss, if present, hit the high frequencies to a minimal degree; a fact that made it almost undetectable. This high ratio of audiovestibular complaints ignited our enthusiasm to probe the audiovestibular system in those candidates.

Tinnitus was either hissing or buzzing. This pitch of sound mostly accompanies high-frequency hearing loss. However, those patients had normal audiograms, normal ABR traces, but mostly a partial pass TEOAE. This fact puts a big asterisk beside TEOAE as a screening tool for subtle cochlear dysfunction. The duration of tinnitus was often less than the duration of the cardiac chest pain. This remark raised a question: Is ischemic heart disease a cause of tinnitus? Or it was just a coincidence. The second answer could gain credibility; but the bilaterality of the tinnitus, its subjective improvement, and the improvement of the TEOAE from a ‘‘partial pass’’ to ‘‘pass’’, all of them, encircled ischemic heart disease as a cardinal etiology.

Patients who were complaining of dizziness experienced mostly a sensation of light headedness for seconds or minutes.

Table 7 Results of preoperative and postoperative sensory organization test (SOT) among patients.

Conditions of SOT	Preoperative X ± SD	Postoperative X ± SD	*P* Value
Condition 1	90.27 ± 2.60	92.27 ± 1.80	0.001***
Condition 2	88.57 ± 2.90	91.80 ± 1.27	0.001***
Condition 3	89.57 ± 2.57	93.10 ± 1.32	0.001***
Condition 4	80.13 ± 4.27	85.23 ± 2.87	0.003**
Condition 5	68.23 ± 10.24	77.13 ± 6.03	0.002**
Condition 6	63.70 ± 9.52	73.27 ± 6.20	0.001***
Composite score	73.33 ± 6.16	80.00 ± 3.54	0.003**

Ischemic heart disease can sometimes be accompanied with temporary arrhythmias [12]. These arrhythmias make the patient feel as if she/he is about to faint, a description referred to as ‘‘light headedness’’.

ABR latency measures were all within the normative range of our laboratory set. When the results of preoperative and postoperative ABR latency measures were weighed, there was a significant difference especially for wave I (Table 4). Wave I latency decreased much more remarkably after treatment than waves III & V. Wave I provides valuable real-time information regarding blood flow to the cochlea. Because the effect of labyrinthine ischemia upon the physiology of the auditory pathway is the primary concern, wave I was monitored closely for any shift in latency. This matched the results attained by Karamitsos et al. (1996) [6]. They reported no significant differences in pure-tone audiometry in individuals with ischemic heart disease compared to age-matched healthy individuals, although there were significant peak auditory brainstem response absolute latency differences between the groups.

The primary purpose of otoacoustic emission (OAE) tests is to determine cochlear status, specifically outer hair cell function as well as the integrity of the stria vascularis. In the current study, TEOAE showed a significant increase in the PASS rate after the operation. This reflected the value of the TEOAE in the detection of the most minimal insults to the cochlea and/or its blood supply. Results of both ABR and OAE clarified the compromise of cochlear microcirculation in the study group.

On the other hand, videonystagmography test did not reveal concomitant variations of the vestibular function related to stent application. However, there was a significant difference between preoperative and postoperative VEMP (Table

Table 6 Results of preoperative and postoperative vestibular evoked myogenic potentials test (VEMP) among patients.

Type of VEMP abnormality	Right ear			Left ear		
	Preoperative	Postoperative	*P* Value	Preoperative	Postoperative	*P* Value
Normal	25 (83.3.0%)	27 (90.0%)	0.001***	25 (83.3%)	27 (90.0%)	0.001***
Diminished amplitude	2 (6.7%)	2 (6.7%)		3 (10.0%)	3 (10.0%)	
Latency shift	1 (3.3%)	0		1 (3.3%)	0 (0.0%)	
Diminished amplitude & latency shift	1 (3.3%)	1 (3.3%)		1 (3.3%)	0 (0.0%)	
Absent response	1 (3.3%)	0		0 (0.0%)	0 (0.0%)	

Table 8 Results of preoperative and postoperative motor control test (MCT) latency scores among patients.

Amplitude scaling	Preoperative X ± SD	Postoperative X ± SD	*P* Value
Medium backward transition	122.20 ± 4.01	125.77 ± 3.26	0.001***
Large backward transition	117.40 ± 2.36	121.67 ± 3.84	0.002**
Medium forward transition	140.50 ± 4.49	142.27 ± 3.18	0.002**
Large forward transition	135.93 ± 4.37	139.17 ± 3.24	0.003**

Table 9 Results of stepwise regression analysis.

Model		Unstandardized coefficients		Standardized coefficients	*t*	Sig.
		B	Std. error	Beta		
1	Constant	6.391	.405		15.770	.000
	Chest pain duration	−.169	−.058	−.480	−2.898	−.007
2	Constant	4.825	.598		8.064	.000
	Chest pain duration	−.170	−.050	−.483	−3.369	−.002
	Chest pain grade	1.150	.356	.463	3.231	.003

a. Dependent variable: total degree of stenosis.

6). Amplitude and/or latency measures-shifted to normal after stent application. VEMP was abnormal in one of the patients who experienced a sense of rotation of surroundings. VEMP assessed the function of the saccule that is supplied by the posterior vestibular artery; which is a branch of the common cochlear artery [13]. As the microcirculation of the whole labyrinth was affected by the low cardiac output, the posterior vestibular artery would not be isolated from such events.

In computerized dynamic posturography, the scores of the sensory organization test (SOT) and the motor control test (MCT) improved significantly after stent application. The scores of the sensory organization test (SOT) and the adopted strategy improved significantly after stent application (Table 7). This denoted a generalized functional improvement postoperatively. Going deeper into the results of the test, conditions (5 and 6) were abnormal in some patients. One of those with abnormal conditions 5 and 6 had also an abnormal VEMP and a sense of rotation of surroundings; a collection of clues that pointed to a possible vestibular lesion. Diagnosis of vestibular lesions demands a battery of tests that complement each other and build up upon each other. It is an interactive process that looks like solving a puzzle.

Ischemic heart disease can be a definite cause of an audio-vestibular complaint. The current work would support that anginal pains and in general-cardiac disorders especially those leading to reduced cardiac output would influence audiovestibular function. These audiovestibular changes have been shown to improve or to reverse to normal after stent application (Tables 4–8).

Clinically, grade and duration of chest pain have been shown by stepwise regression analysis as the best predictors of coronary artery disease (Table 9). Consequently, the inclusion of a question about anginal chest pains in the audio-vestibular examination looked to be valuable and informative to audiologist to suspect cardiac dysfunction for referral.

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